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CHEMICAL & ENGINEERING NEWS

C&EN

MAY 30, 1994

EPA DRAFT DOCUMENT CONCLUDES THAT DIOXINS ARE HEALTH RISK PAGE 13

PLASTICS IN CONSTRUCTION

New building products take growing share at expense of traditional materials
Page 20

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CHEMICAL & ENGINEERING NEWS

C&EN

MAY 30, 1994

NEWS OF THE WEEK

■ Scripps scientists have carried their work on peptide nanotubes further, forming artificial ion channels in cells that may offer way to insert drugs into cells. **Page 4**

■ Genzyme has received FDA okay to market recombinant form of an enzyme, the first recombinant "housekeeping" enzyme, to treat Gaucher's disease. **Page 5**

■ Fighting hard to ward off Administration plans to temporarily freeze indirect research cost payments, university representatives propose cutting research budgets instead—infuriating research scientist association. **Page 5**

■ Senate committee contends U.S. troops in Gulf War were exposed to harmful levels of chemical and, possibly, biological warfare agents, contributing to recently reported health problems. **Page 6**

■ Several environmental activist groups have sued EPA in an effort to force it to disclose the inert chemicals used in pesticide formulations, charging that these chemicals are neither safe nor inactive. **Page 6**

■ Chemical firms support Clinton's decision to keep China's "most favored nation" trade status, argue that any sanctions would be counterproductive. **Page 7**

COVER: Workman applies Eiger Building Products' roofing sheets that look like cedar shake shingles but are made of General Electric's polyphenylene oxide resins

Volume 72, Number 22
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BUSINESS

Flavors and fragrances business has grown steadily, is more like the drug business than the chemical industry in innovation, R&D spending, and merger activity, says head of Haarmann & Reimer, flavors and fragrances arm of Germany's Bayer. **Page 10**

GOVERNMENT

Part of EPA's risk assessment study of dioxins and similar compounds suggests dioxins, furans, and polychlorinated biphenyls have potential for harming humans and the environment. **Page 13**

Group assessing National Institute of General Medical Sciences' predoctoral training programs finds programs are doing a superb job, suggests need for more data to really judge success. **Page 14**

SCIENCE/TECHNOLOGY

New technique to immobilize enzymes in polymeric microcapsule arrays that look like bristles on a brush may find application in bioreactors and biosensors. **Page 17**

STN International, the on-line science and engineering database begun by ACS's Chemical Abstracts Service and FIZ-Chemie in Germany, celebrates 10th year of service. **Page 18**

EDUCATION

Five high school students from Atlanta win fourth annual National Science Bowl, edging out a team from Houston; winners will research endangered wildlife in Switzerland. **Page 19**

MEETINGS

13th International Conference on Chemical Education, to be held in Puerto Rico in August, features symposia and workshops of interest to precollege and college chemistry teachers. **Page 49**

PRODUCT REPORT

Use of plastics in construction and building has been increasing moderately as manufacturers strive to develop products that can compete—in cost and performance—with traditional materials. **Page 20**

LETTERS 2

CONCENTRATES

Business 8

Government 12

Science/Technology 16

THE DEPARTMENTS

New Products 44

Awards 47

Newscripts 64

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LETTERS

Questions about ISO registration

I compliment Ann Thayer for her comprehensive article on ISO 9000 registration (C&EN, April 25, page 10). The article points out aspects of this currently popular rush to registration that I find troublesome.

For example, on page 10, Thayer states, "ISO 9000 is not a product certification standard; registration in no way measures or recognizes the quality—good or bad—of a company's final product." On page 17, she writes, "Companies that use 9000 registration as a trophy or a blue ribbon are met with suspicion, if not derision, by quality managers. And customers unfamiliar with the details of ISO 9000 registration may be too naive to know better."

Yet in the very same issue of C&EN, there are three full-page ads from chemical companies that prominently proclaim ISO 9002 registration and imply they have superior quality products as a result. Let us all not be naive about this. Marketing departments are clearly promoting ISO registration to portray their products as somehow being of better quality than those of competitors who are not registered. The clear inference is that quality products are only achieved if companies belong to the ISO fraternity.

I also have a great concern about what this mad rush to ISO registration means to the future of small entrepreneurial companies. It is difficult enough for many entrepreneurs to break away from the security of a large company. Now they must also face the prospect of being locked out of markets unless they submit to the bureaucracy and cost of ISO registration and the accompanying third-party auditing of their operations. To many prospective entrepreneurs, this may be the deciding factor that keeps them from venturing forth.

Ironically, as a result of novel designs and fabrication techniques, quality has been one product feature on which small companies can often compete quite successfully with companies of much larger size. I believe that all companies, large and small, should have as a prime objective the continuous improvement of the quality of their products or services. However, I also believe in the contingency theory of organizations that states that what is right for one business is not necessarily right for another.

What of the companies that have achieved product quality on their own? Are they to be required to join the ISO fraternity just to stay in business? Will end customers really be better off without fresh new ideas and products that are traditionally spawned by entrepreneurs and small companies? What ever happened to the free-enterprise system whereby companies that made poor quality products simply did not survive in business? Is ISO registration being misused by some companies to project an image of perceived quality when real quality does not exist because of poor product design?

For many small companies, I wonder whether quality might better be maintained by instilling in their employees a sense of personal pride and ownership in the products they produce. To this end, funds that might otherwise be spent for outside registrars and auditors could better be directed to enhanced employee benefits and equity sharing in the success of the company.

Paul L. Patterson
Walnut Creek, Calif.

Respect for interviewees

As the spouse of a Ph.D. chemist who is currently seeking employment, I am writing to make your professional community aware of the deplorable treatment of interviewees for academic and industrial positions in chemistry. My husband has been invited on interviews by a variety of institutions and agencies, has gone through the usual process of presenting his research and speaking with faculty and staff, and then has left the interview process never to be contacted again. In some cases, he has received form letters three or four months later informing him that the position was canceled or filled by another individual, and thanking him for his time. I will not belabor my husband's impressive credentials and publication record; such disrespect is inexcusable toward any job applicant, irrespective of his or her qualifications. Nor is my husband's experience unique; in fact, his peers at three different research institutions confirm the universality of this practice.

Let me contrast this with my experience of the interview process for psychologists. In any institution or agency I have worked with, staff has been acutely aware of the

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vironmental Law Center, also of Eugene, a public interest law firm.

The dispute centers on chemicals used in pesticide products that are not the active ingredients. These so-called inerts often compose the bulk of a product, and NCAMP says that there are more than 2,300 substances used as inerts. Because these compounds are essential to the product formulation, chemical manufacturers often claim inerts are confidential business information.

NCAP and NCAMP complain, though, that these chemicals may be neither safe nor inactive. In their lawsuit, the groups list several compounds used as inerts, and thus not listed on product labels, that are actually canceled or registered pesticides. These compounds include acetone, dibutyl phthalate, *m*-cresol, and naphthalene. Some inerts are also regulated as hazardous chemicals under the Resource Conservation & Recovery Act, NCAP says.

The citizen groups claim that because these compounds can be harmful, EPA has an obligation to tell the public when they are present in a product. To further complicate matters, NCAMP says companies sometimes will release the inert information to outside groups on request, even while EPA withholds the data.

For its part, EPA says it is following the Federal Insecticide, Fungicide & Rodenticide Act (FIFRA) by not releasing inert data, but it can if the compounds seem to present health risks. EPA has no official comment on the lawsuit at this time, according to a spokesman. He adds that EPA has taken action against some inerts in the past when health problems arose, but admits that the agency does not have health effects data on all the possible inert ingredients.

The National Agricultural Chemicals Association, which represents pesticide makers in Washington, D.C., says its member companies are telling EPA what is in each product as required by FIFRA. Also, manufacturers are making this information available to state and local poison control centers for emergency treatment if necessary.

David Hanson

U.S. chemical firms back China trade benefits

U.S. chemical companies will welcome President Bill Clinton's decision last week to seek renewal of China's "most favored nation" (MFN) trade status.

Chemical firms expressed strong opposition to U.S. imposition of trade sanctions in response to China's human rights and other policies. Such sanctions, the firms argued, would be counterproductive: They would harm U.S.-China trade and provoke Chinese countermeasures that could damage growing chemical trade and investment. Moreover, the firms believe, U.S. sanctions would not persuade China to pursue values and policies the U.S. seeks.

A report by the Congressional Research Service (CRS) notes that withdrawal of MFN status would raise tariffs on many imports from China to prohibitive rates. Chinese retaliation "would not likely have a significant *overall* effect on the U.S. economy" but could hurt "vulnerable" U.S. exports of materials readily obtainable from other suppliers, including chemicals and allied products (such as fertilizers) and plastics.

The U.S. has a highly favorable chemical trade balance with China, with exports exceeding imports by $700 million to $1.3 billion during 1988–92. Last year, the surplus plummeted to $263 million.

For example, China bought $293 million worth of U.S. fertilizers in 1993, 16% of all U.S. fertilizer exports. Of the top 15 U.S. exports to China, fertilizers would be hit the hardest by cuts in Chinese purchases, CRS finds.

China imported $386 million worth of U.S. industrial chemicals in 1992, out of $2.5 billion in total imports. U.S. exports are projected at $432 million for 1993, with 12% growth per year from 1993 to 1995. "U.S. firms face stiff competition" from Chinese and foreign producers, CRS says.

U.S. exports of plastic materials and resins to China hit $464 million in 1992, out of $4.8 billion in total imports. U.S. sales of $361 million are projected for 1993, falling 12% per year from 1993 to 1995 under steep competition.

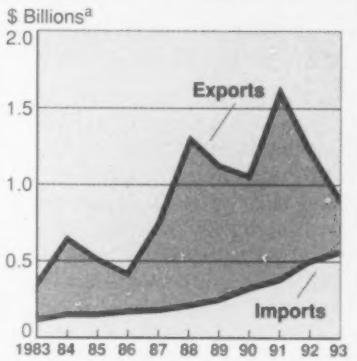
The Fertilizer Institute, representing that industry, has been monitoring the MFN issue closely. The institute wrote a key member of Congress that "Revocation of MFN status will only harm U.S. interests without helping the people of China. China will easily find other sources of needed materials and feel no foreign policy pressure." Meanwhile, the Society of the Plastics Industry last week adopted a statement backing continued MFN status for China.

Chemical companies that belong to the Chemical Manufacturers Association have sought MFN renewal for China—without conditions attached—through umbrella groups like the Business Coalition for U.S.-China Trade. A letter to President Clinton from the coalition includes a number of chemical firms among its hundreds of signatories.

The letter stresses that MFN can be a catalyst for human rights—as economic development, and foreign trade and investment, spur evolution toward a more open and democratic society. "In China, American trade and investment advance American ideals," it says. "Over the last decade, the driving force for economic and political reform has been the emergence of a dynamic and entrepreneurial private sector."

Richard Seltzer

U.S. chemical trade with China has falling surplus



a For chemicals and related products.
Source: U.S. Department of Commerce

Fertilizers top U.S. chemical exports to China

$ Millions	1993 Exports	1993 Imports
Organic chemicals	$204	$127
Inorganic chemicals	25	134
Dyeing & coloring materials	29	39
Pharmaceuticals	27	126
Oils, perfumes & cleansing products	21	35
Fertilizers	293	0
Primary plastics	168	16
Nonprimary plastics	22	6
Other chemical materials & products	51	92
TOTAL	$839	$576

Source: U.S. Department of Commerce

Flavors And Fragrances Business Marked By Growth, Mergers

■ ***Haarmann & Reimer chief says industry is like pharmaceuticals in innovation, R&D spending, consolidation***

Patricia L. Layman, C&EN London

The rest of the chemical industry may have been through some down times in recent years, but the flavors and fragrances industry has enjoyed steady growth. Producers are finding increases not only in their home markets; indeed, they are scrambling to cater to the double-digit growth now occurring in many Asian countries.

As Hans Hartmann, president and chief executive of Haarmann & Reimer, the flavors and fragrances arm of German chemicals giant Bayer, notes in a C&EN interview: "The industry has continued to grow about equally with consumer goods growth. Even when other industries were down, ours showed some growth," certainly better than the average of the chemical industry.

Moreover, even though growth has slowed somewhat, it is still roughly 3 to 5% on an annualized basis for perfumes and aroma chemicals, and slightly higher for food flavors. That continues the solid performance the industry has shown for decades.

Now worth nearly $9 billion worldwide, of which $4 billion is fragrances and $5 billion flavors, the industry has long been seen as attractive and profitable. Profitable enough, for example, to have caused otherwise sensible chemical and consumer-goods companies to snap up flavors and fragrances producers in the 1970s—moves that nearly all turned sour.

The result has been divestitures of flavors and fragrances operations, usually to companies already in the business. Additionally, mergers have continued, as producers work to become large enough to handle international business.

The only publicly traded flavors and fragrances company is International Flavors & Fragrances, which probably accounts for about 13% of total industry sales. In 1993—"another year of solid growth," as the company puts it—pretax profits climbed 15% from those of 1992 to $324 million. Sales were up 6% to $1.19 billion, of which fragrances were $699 million and flavors $489 million.

The other major companies in the business are either subsidiaries of large multinationals—Givaudan, of Roche Group, Switzerland; Quest, of Anglo-Dutch Unilever; Haarmann & Reimer, of Bayer—or privately held, as is Swiss-based Firmenich. These five—International Flavors, Givaudan, Quest, Firmenich, and Haarmann & Reimer—account for nearly half of flavors and fragrances sales.

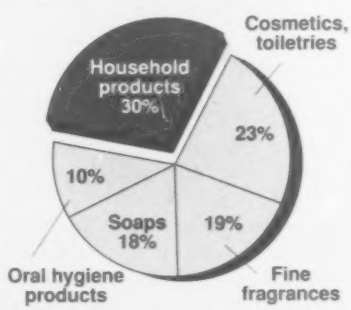
Several other companies are much smaller than these five producers but are still significant players in the business. These are Bush Boake Allen, U.S.; Takasago, Japan; Dragoco, Germany; Florasynth, U.S.; Sanofi, France; and Tastemaker, a joint venture of Hercules' PFW Flavors and Mallinckrodt's Fries & Fries.

And most of them would argue that one of the reasons earlier purchases by big chemical companies went awry is that "We are not chemical companies," as Hartmann puts it, but more akin to drug companies in the way they approach innovation. His own company, for example, now spends about 7% of total sales on research and development—the same proportion as a pharmaceutical company would spend (a chemical company would spend 3 to 4%). For Haarmann & Reimer, that means last year's R&D spending was roughly $60 million—7% of 1993 sales of $856 million. Sales in 1993 were double those of five years ago.

The high level of R&D spending—in part to cope with increasingly stringent environmental requirements, flavor and fragrance safety testing, and the need to serve international customers—is driving mergers in the industry, Hartmann says. The mergers have tended to be between large- and medium-sized companies, as management faces the daunting prospects of finding the resources to follow those trends or to expand operations.

Hartmann: not chemical companies

Household products are biggest use of fragrances



1993 fragrances sales = $4 billion

Nonetheless, a sizable number of small- to medium-sized companies remain in the flavors and fragrances business, he adds. But their options are becoming limited: Either they are local suppliers, or they "have to play a world game."

Hartmann is well poised to do this. Despite his assertion that "we are not chemical companies," Hartmann's background is in Bayer's chemical operations. He joined Haarmann & Reimer's board in 1987 and took over last May as chief executive, succeeding Claus Skopalik, who had been in the company's top management for 25 years.

However, pitched from the chemical industry into a world dominated by sensuality and artistic talent, Hartmann had a saving grace—he came from Bayer's dyes and colors business. When he was visiting the various Haarmann & Reimer sites to get to know the business, one perfumer asked him his background. Dyes and colors? "Ahh, colors—then you will know about beauty," Hartmann was told.

Whether these particular talents will serve him well in the global marketplace is not yet known. One "must-enter" marketplace, Hartmann says, is Asia, with its heady, double-digit growth rates. That, he emphasizes, includes China. "It is a big race: Who will be there first?" he asks.

"In Asia now, multinational consumer-goods companies are investing heavily in China—from soft drinks to detergent powders, noodle soups to cosmetics. These are not only Western multinationals, but Japanese, Taiwanese, Indonesian, and so on. They are our customers in their own countries, and we are asked to move with them," he points out.

"Only major companies can [make] this kind of investment—another reason why more and more companies in our industry are going through mergers. Our customers are becoming more global. They don't need dozens of suppliers."

In January, Haarmann & Reimer opened a new Singapore plant to expand sales operations it already had there. The new Singapore complex is dedicated to flavors and fragrances and includes offices, laboratories, a warehouse, a utility and workshop building, and a flavor-compounding plant. The first production unit was built to make flavors. And more construction is in the works: The next phase of the project will consist of fragrances production facilities.

Additionally, notes Hartmann, "We have [company] people in Shanghai and Canton, actively selling. We are investigating the best way of setting up compounding facilities for this growing market."

Although there is plenty of action in that region, he adds, "we are not neglecting other areas. For example, the U.S. is doing well, and there is growth in Europe."

Each of the regions tends to have individual characteristics. The split in the fragrances market is roughly equal between Europe and the Americas, but in the flavors business, it is significantly different. The explanation is simple, says Hartmann. "Look at the number of people. For this, the comparison is the U.S. and Europe, where the amount of use is comparable. Latin America is not as developed."

Even for food, however, globalization is becoming more of a trend. "Taste is still a local thing, but flavor can be produced anywhere in the world—it doesn't have to be produced in Bavaria or Greece."

And in supplying, no matter where, customer expectations as well as legal requirements are adding to the constantly increasing costs of product testing and complaints. This develops into a significant cost factor to be considered in the price calculation.

Apart from flavors and fragrances compounds, there are some quasi-commodity flavors and fragrances products in Haarmann & Reimer's product portfolio like *l*-menthol. Synthesis of this compound is one of the company's important achievements, Hartmann concedes, "to compete with natural menthol or citric acid and biochemistry products fermented from carbohydrates. Menthol prices may go up next year after a couple years of decline," following tightening availability of natural product from India and China, the big suppliers.

To help avoid being hit by commodity product cycles, Haarmann & Reimer is broadening its range of aroma chemicals to include specialties such as ultraviolet absorbers and cooling agents based on menthol technology for sunscreens and cosmetics.

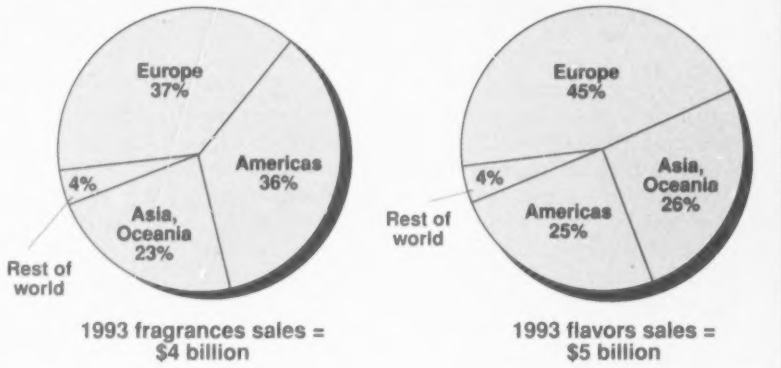
Four years ago, the firm strengthened its small business in fine fragrances when it purchased, from Mallinckrodt, Créations Aromatiques, a designer house for fine fragrances. This has been kept as a business with a separate identity, and studios in Paris and New York City compete with Haarmann & Reimer's own studios in both cities. Two years ago, the company acquired the fragrance business of PFW.

And a similar sensitivity to separate markets and cultures is one reason the company's relationship with parent Bayer has worked so well, Hartmann believes.

"We have with Bayer an arm's length relationship," he says. "They love us, but leave us independence. Haarmann & Reimer is a company with its own history and success—it has grown and been profitable.

"In business as long as you are good, you have a lot of freedom. They realized early on that we are much closer to consumer goods, that our business has its own technical expertise, and that it is not in the interests of the business if it is just put into the big pot" along with all of Bayer's chemical operations. "Now, a lot of companies are decentralizing management to give people room to succeed. Bayer has always given us the autonomy." □

Fragrances, flavors use pattern differs geographically



brings up the problem of indirect risk assessment, according to Pirages. To calculate the uptake of these compounds by humans, calculation of the uptake by other animals used for foods, such as beef and fish, is necessary. Pirages says there is some inconsistency in the way EPA calculates this indirect exposure that results in risks higher than are reasonable.

The principal problem she has with the indirect assessment is that EPA assumes that TCDD in the vapor phase is taken up by plants that are eaten by animals which are, in turn, eaten by people. She says the chemical properties of TCDD—particularly that it attaches to particles very strongly and that very little TCDD seems to exist in the vapor phase—make this "a questionable assumption." She also takes exception to EPA's use of 1978 dietary data to calculate approximate TCDD uptake because diets have changed significantly in the past 15 years, especially meat consumption.

The EPA characterization reviews the toxic effects of TCDD and related compounds, devoting a lot of discussion to carcinogenicity and to reproductive toxicity. The draft report concludes that all available data indicate that TCDD and related compounds increase cancer mortality. Similarly, EPA finds that exposing fish, birds, and mammals to these compounds causes several developmental defects, even at concentrations below those originally thought to have no effect.

Pirages is wary of extrapolating low-level effects in animals to humans because these same health effects have not been observed in humans who have been exposed to high levels of TCDD, either in industrial workplaces or by accident. If there are human reproductive problems caused by TCDD, she asks, why have such effects not been noted over the past 20 years when TCDD levels in humans were increasing? She thinks EPA has not taken a close enough look at the available human data in making some of the assumptions used in the draft study.

Pirages also thinks the agency did not provide enough information about its assumption in this chapter. "At a minimum, I would have liked to have seen in this chapter a greater discussion of the uncertainties inherent in their evaluation process. When they talk about the food chain exposures, I would have liked to have seen them acknowledge within this chapter that there are uncertainties in the assumptions that have been made, and the impact that these uncertainties would have on their estimates of risk. That way, a person reading this chapter could make [his or her] own judgment based on the information about those uncertainties," she says.

Concern over the toxicity of TCDD and related chemicals is high because people are already carrying significant levels of these compounds in their bodies. The report estimates total body burden for all dioxinlike compounds to be as high as 60 ppt Significantly, this exposure is 500 times higher than what EPA proposed in 1985 as a safe level of exposure for a one-in-a-million risk of cancer. And it is still 150 times higher than the safe dose proposed in other parts of the TCDD risk assessment. EPA wonders if higher exposed populations, such as those that eat a lot of contaminated fish, might already be experiencing adverse effects from these compounds.

EPA is expected to complete its review of the draft risk assessment and issue the final report this summer. The considerable time taken to evaluate TCDD and related compounds will give the agency a benchmark by which to measure future assessments of toxic chemicals. If, however, there are still basic disagreements about the assumptions EPA has made, whether because of insufficient data or public policy considerations, risk assessment will continue to be a source of debate instead of a fundamental basis for environmental management.

David Hanson

NIH unit assesses predoctoral training programs

The National Institute of General Medical Sciences' (NIGMS) predoctoral training programs are doing a superb job of preparing graduate students for careers in biomedical research, a group of scientists and university administrators agreed during a recent discussion at the National Institutes of Health's Bethesda, Md., campus. The group advised NIGMS staff not to be too eager to alter the structure, organization, or operation of the 20-year-old effort.

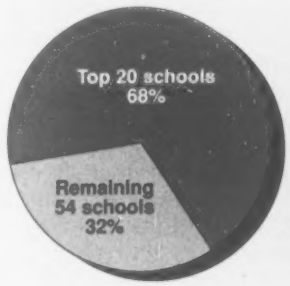
Yet, at the same time, the group acknowledged there is little concrete data regarding the subsequent careers of Ph.D.s who received support from NIGMS during graduate school. Evidence for the programs' apparent success is largely anecdotal. And many in the group worried about potential lack of diversity because the programs are concentrated at a limited number of schools.

Acting NIGMS director Marvin Cassman invited a dozen scientists from around the country to join the institute's advisory council's regular spring meeting for a discussion of NIGMS programs for supporting graduate students through training grants to universities. Under the authority of the National Research Act of 1974, NIH funds the majority of biomedical research training programs in the U.S. Within NIH, NIGMS programs represent about half of the total effort and NIGMS will spend about $80 million on predoctoral training grants this fiscal year.

"After 20 years, it's worth asking if we've got it right," Cassman told the group. "We want to hear your opinions and concerns." Cassman stressed that the discussion was just the beginning of a process of assessing NIGMS programs and that any suggested changes would be discussed in greater depth before being implemented.

NIH supports predoctoral students via a different mechanism than the National Science Foundation's graduate

Twenty schools enroll most predoctoral trainees



1993 total = 2,200 trainees

Source: National Institute of General Medical Sciences

fellowships, which are awarded to individual students for use at the universities of their choice. NIH training support is awarded to institutions. The universities then fill their given number of slots with graduate students, most of whom are supported by the training funds for their first two years of study before being picked up under research grants.

At most NIH institutes, training programs are oriented toward clinical and disease research, said John C. Norvell, NIGMS assistant director for research training. NIGMS, in contrast, focuses on providing graduate students broad exposure across disciplinary lines. The four interdisciplinary predoctoral programs established in 1974 have changed little over time. They are cellular, biochemical, and molecular sciences; genetics; pharmacological sciences; and systems and integrative biology.

However, three new programs have been added since 1987. The molecular biophysics program, supported by funds for AIDS research and training, emphasizes structural biology and structure-based drug design related to AIDS. The biotechnology program was mandated by Congress in 1987 and involves interaction among industry and universities. The chemistry-biology interface program, initiated last year, is designed to bring more students from chemistry into the biomedical field.

NIGMS requires cooperation among faculty from different departments in providing course work and laboratory rotations, Norvell explained. The participating universities are also required to actively recruit students from underrepresented groups and to provide training in the ethical conduct of research.

Although only about 15% of the nation's biomedical graduate students are supported by training grants, the standards established by NIGMS programs have a ripple effect that gives the programs much broader influence, according to scientists participating in the discussion. Particularly valuable is the requirement for interdisciplinary work, said Marian Carlson, professor of genetics and development at Columbia University, New York City. "Graduate students need broad exposure and time for wide experience before choosing an area of specialization," she explained.

Manuel Navia, vice president of Vertex Pharmaceuticals, Cambridge, Mass., agreed that NIGMS guidelines have been valuable in helping to shape how young researchers are trained. "I've seen how NIGMS guidelines have had a great impact in clearing away the debris and allowing a student to pursue what is in his or her soul," said Navia, who has served as a reviewer for universities' training grant proposals.

Navia noted that his biotechnology firm is a consumer of the finished product of NIGMS training programs—biomedical researchers. "Overall, they have done a very good job," he said. Then Navia added this advice: "Be slightly conservative about tinkering with tremendously successful programs."

But Franklyn G. Prendergast, professor in the Mayo Foundation's department of biochemistry and molecular biology in Rochester, Minn., pointed out the lack of concrete data needed to really judge the programs' success. "A predicate for our discussion is that we have, in fact, produced a wonderful product," he told the group. "Do we know that? What criteria do we use? I find myself uncomfortable until I know."

Prendergast also cautioned the group to pay attention to the realities of the tight federal budget. "How many training slots do we really need?" he asked. "Are we deluding ourselves that in a zero-sum game we can support all these training sites?"

A draft report by the National Research Council's Committee on National Needs for Biomedical & Behavioral Research Personnel echoes Prendergast's concern. Under the National Research Act, NRC reports periodically to Congress on the need for biomedical researchers and the kinds of training that should be provided them. The most recent report, due to be released later this spring, endorses continued support of predoctoral training in the basic biomedical sciences but notes that "surprisingly few systematic studies are available of the career outcomes" of trainees.

The concentration of training grants within a relatively few universities was disturbing to many of the scientists and administrators. Just 10 schools, led by Harvard, Johns Hopkins, and Yale universities, receive 43% of NIGMS training grants. The group acknowledged that the skewed distribution may be due to merit rather than any inequity, but found the potential lack of diversity troubling.

"Of course, it is important to reward merit," said Susan Gerbi, biology professor at Brown University in Providence, R.I. "But it's important to broaden the base to maintain a diverse wellspring of ideas. You don't want all the trainees in the country hearing the same input."

Cornell University chemistry professor and vice president for planning John R. Wiesenfeld summed up the group's thinking about NIGMS's training effort overall: "If it ain't broke, don't fix it," he said. "I'm not sure the system is broke. However, I can guarantee 2004 will be a lot different than today. That the system is not broken today should give us cold comfort. The issue is: How well are the programs preparing biomedical scientists for tomorrow?"

Pamela Zurer

Broadest NIGMS programs enroll the most trainees

Number of trainees	Fiscal year							
	1986	1987	1988	1989	1990	1991	1992	1993
Cellular, biochemical and molecular sciences	825	907	895	833	743	774	780	755
Genetics	353	383	370	370	362	367	373	367
Biotechnology	—	—	—	83	162	274	298	314
Pharmacological sciences	253	258	259	262	288	276	276	279
Molecular biophysics	—	—	100	192	222	250	251	254
Systems and integrative biology	183	218	214	200	216	214	202	208
Chemistry-biology interface	—	—	—	—	—	—	—	23
TOTAL	1,614	1,766	1,838	1,940	1,993	2,155	2,180	2,200

Source: National Institute of General Medical Sciences

Plastics In Building And Construction

Marc S. Reisch,
C&EN Northeast News Bureau

Use of these versatile materials grows moderately as manufacturers continue to push for wider acceptance in the building trades

Plastics in the huge U.S. construction market continue to make inroads in areas traditionally held by such building stalwarts as concrete, wood, steel, and glass. Although the use of most plastics probably won't grow much more than the overall construction industry grows in the near future, some applications—such as for certain types of window frames and house siding—are expected to grow dramatically.

Plastics used in building and construction are valued at about 7%, or $5.6 billion, of the $80 billion total for building and construction materials used annually in the U.S., according to New York City-based consulting firm Frost & Sullivan. However, by weight, plastics account for less than 2% of new construction materials used each year, a figure that partly reflects the relative light weight of plastics.

Although the size and value of the overall U.S. construction industry is difficult to pin down, the Department of Commerce estimates that in 1993 the value of all new construction was about $460 billion. Include the value of additions, alterations, reconstructions, maintenance, and repair, and the value of all construction leaps to more than $750 billion.

Plastics may occupy a relatively small niche in this market, but they accounted for nearly 20%, or 12 billion lb, of the total 60.6 billion lb of all plastics produced in the U.S. in 1992, the most recent year for which such break-outs are available, according to the Society of the Plastics Industry, in Washington, D.C.

Among uses for plastics that are expected to grow only modestly are piping, flooring, vapor barriers, and bonding agents for wood products. However, some uses, such as building siding and window frames, are expected to grow more dramatically as plastics continue to supplant more traditional wood and aluminum materials in those areas.

Some visionaries expect to see wide use of composite plastic and fiberglass materials such as structural framing members, and even as components in civil engineering projects such as bridge decks. But high costs relative to costs of traditional materials limit these uses at present to specialized structures for which a client is willing to pay for a performance advantage that composites may offer.

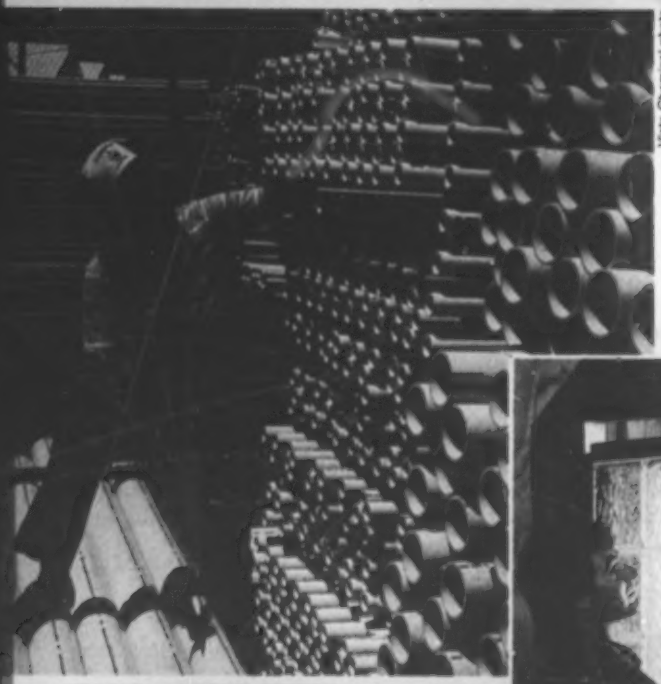
Some plastic composite buildings already in use are, for example, those in which electronics manufacturers test their equipment to meet Federal Communications Commission (FCC) specifications. The plastic structures, free of metal, are suitable for all-weather equipment testing because the buildings are transparent to electromagnetic radiation.

But plastics still confront formidable barriers to gaining market share in building and construction uses. James Virosco, a principal with consultant firm Chem Systems, Tarrytown, N.Y., points out that the building industry is mature and slow growing. Housing starts are mediocre, he points out.

Virosco notes other barriers. Design standards for traditional wood and steel are well understood, he says; those for most plastics and the more exotic composites are not. So it will take time for architects to become comfortable working with plastics, and it will also take time for wider acceptance for plastics and composites use in building codes.

Richard M. Kossoff, president of consulting firm R. M. Kossoff & Associates, New York City, adds that a barrier to code acceptance of plastics is concerns about toxic smoke that may be generated when some plastics burn. He also thinks that the increased plastics use in building and construction is not growing as fast as once expected because there have been no major improvements in plastics to meet demanding building performance requirements. Talk some years back about the potential for carbon fiber plastic composites for structural framing never materialized because of the persistently high cost of carbon fiber.

More recently, performance problems have plagued the use of at least one plastic in new plumbing installations. The Washington Suburban Sanitary Commission, covering Montgomery and Prince George's Counties in Maryland, adjacent to Washington, D.C., joined other municipalities in banning installation of new polybutylene pipe because numerous breaks have caused flooding and damage to hundreds of homes (C&EN, May 23, page 9). Shell



Vista Chemical photo

General Electric photo

BASF photo

Amoco photo

Other natural disasters have also increased demand for wood and other building products: flooding in the Midwest along the Mississippi River during 1993, destructive wildfires in Southern California also in 1993, and the earthquake that did considerable damage in the Los Angeles area earlier this year. As prices for wood products have risen, plastics use has become more attractive.

Vinyl is used most widely

Plastics most widely used in building construction are the commodity-priced large-volume resins, such as PVC, polyethylene, and polystyrene. Some resins—considered engineering resins because of their higher performance, heat tolerance, and price relative to commodity resins—are also useful in building and construction products. Engineering plastics used in construction include polycarbonate, acetals, and polyphenylene oxide. However, these plastics are only used where their higher cost can be justified relative to the use of more traditional wood, glass, or metal materials.

PVC is now—and probably will remain for some time—the dominant resin used in building and construction. Its cost and performance make it among the most attractive replacements for wood and aluminum, particularly in the siding and window frame markets. A recent study from industry consultant Freedonia Group, based in Cleveland, pegs 1992 demand for all construction plastics at 12.7 billion lb. Of that, PVC accounted for almost half, 5.6 billion lb, and is expected to grow at more than 4% annually through 1997.

Phenolics are the second largest group of construction plastics, according to the Freedonia study. They are used for electrical devices and laminating plywood. Phenolics demand in 1992 was about 2.2 billion lb and growth is projected at just over 3% annually through 1997. Use of urea and melamine resins, the third most widely used plastics, totaled 1.4 billion lb in 1992. Used in the formation of countertop laminates and wood particle boards, demand for them is expected to grow almost 5% annually.

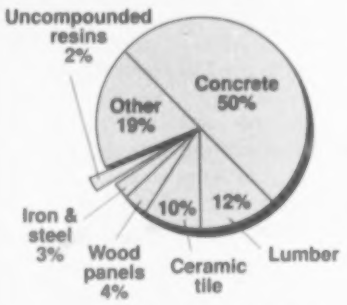
Polyethylene use totaled 942 million lb in 1992 and is expected to grow about 4% annually through 1997, according to

Oil, which is the sole U.S. polybutylene producer, says it "regrets" the commission's action and is "reviewing" it. Polybutylene's share of the potable water pipe market is small, whereas polyvinyl chloride (PVC) and chlorinated PVC are much more widely used as plastic alternatives to copper.

Still, various plastics construction products have an edge because of their insulation properties, ease in handling, or better durability. In addition, although prices for most plastics have been moderate over the past few years, prices for wood products have soared.

Concern over the destruction of the northern spotted owl's habitat in the Pacific Northwest has prevented timber harvests on 7 million acres of federal and state lands. Meanwhile, demand has been high for wood to rebuild in devastated sections of southern Florida, Louisiana, and Hawaii where hurricanes wreaked havoc late in 1992.

Plastics constitute 2% of building materials



Total 1992 use of building materials[a] = 446 billion lb

a Excludes resins used in applications such as water distribution, gas, and sewer systems pipe; telecommunication wire; sealants, caulks, and adhesives.
Source: Philip Townsend Associates, Houston, study for the American Plastics Council

Freedonia. This resin is often used for gas pipe and wiring conduit. Polyurethanes, used largely for insulation, are expected to grow more than 4% annually from 1992 demand of 875 million lb. A category of "other resins," including polycarbonates, acrylics, and polystyrene, represented an additional 1.6 billion lb in 1992 construction demand.

Consulting firm Frost & Sullivan identifies plastic pipe as the largest segment of the construction industry market for plastics. In 1992, the company says, the value of PVC's share of this market was nearly $1.8 billion.

According to Gary Draper, president of Vista Chemical's olefins and vinyl division, roughly three quarters of all PVC manufactured goes into the building and construction market. About 40% of the PVC sold goes into pipe for water mains, sewers, commercial applications and domestic water service. Another 25% goes to the manufacture of "profiles": residential siding and window frames. PVC coating for wire and cable accounts for another 5% of the PVC market. Current PVC demand is at its peak, says Draper, not only because of the peak demand for PVC during the building season from February to July, but also because of continued strength in the housing market compared with the 1991 recession.

The siding and window frame markets are growing the fastest. Draper says although PVC siding was applied mostly on existing homes, it has gained acceptance for use on new homes as well. Use of PVC siding in 1993 grew 17% from 1992, by Draper's reckoning, mostly because of its use in new construction.

PVC for use in window frames grew 10% in 1993, says Draper. High lumber prices along with a rebound in the housing market propelled PVC growth for windows, he says. PVC offers more insulating value compared with an equal thickness of wood, Draper points out, so the use of PVC windows offers an energy savings advantage to home buyers, too.

Draper expects continued growth for PVC in a developing market in sewer repair. Vista Chemical offers a flexible resin, Vynaprene, to produce "somewhat flexible" PVC pipes that can be pulled through cracked cast iron or concrete line to repair them. The PVC pipe receives a heat and pressure treatment in place, allowing it to expand inside the pipelines under repair, sealing any cracks and leaks.

Fred Sacks, marketing director for Occidental Chemical's vinyls division, says the PVC business is brisk now as this construction-driven polymer benefits from the recent strength of the construction market. He also estimates that about 75% of all PVC produced is tied to the construction market not only for pipe, siding, windows, wire, and cable, but also for roofing, earth-lining geomembranes for ponds and landfills, and floor tiles.

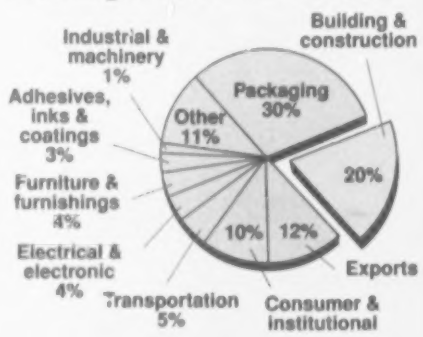
Sacks estimates that pipe represents 45% of the PVC market. He says that advances in manufacturing pipe allow the production of a pipe with a hard PVC inner and outer shell, but with a foamed PVC inner core. Such a pipe is lighter in weight than a solid PVC pipe, uses less material than the solid pipe, and thus is lower in cost. Pipe producers are making the foamed pipe in diameters up to 4 inches, and it is used in residential drainage systems. While Sacks admits the pipe may cost him some business initially because it uses less resin than the solid pipe, the foam-core pipe is a better product and will help PVC to continue to replace cast-iron pipe. With the strong housing market for PVC, producers of the resin are losing very little business because of the growing foam-core-pipe business.

Advances by pipe manufacturers have also contributed to the growth of large-diameter PVC pipe for use in municipal sewer systems, says Sacks. Helically wound extruded profiles of PVC now compete with 24-inch to 48-inch cast concrete, he says. Manufacturers are also extruding similarly large, or even larger diameter, ribbed PVC pipes that have the strength to compete in the market for storm-size sewer pipe. Lighter than concrete or metal pipes, these PVC pipes allow for greater installation productivity, Sacks says. The PVC resin also better resists the effect of aggressive soils, such as Florida's high-sulfur soil, making for a longer lasting pipe system.

John Russ, vice president of Borden Chemicals & Plastics in Geismar, La., says construction demand for PVC is "really booming." PVC suppliers are unable to satisfy export demand for the resin. Export prices are on the rise because of the supply-and-demand situation, he says. Most of the advances in pipe and siding uses of PVC result from advances in processing. Resin producers are concentrating on providing a consistent, quality product, to help along those advances in processing.

A spokesman for Geon points out that existing home sales are much higher than new home sales. Thus, the remodeling market for PVC used in siding, new windows, and flooring is large. And the do-it-yourself market for vinyl products is growing along with the expansion of "home center" warehouse-type sales outlets throughout the U.S.

Building market used almost 20% of plastics made in 1992



1992 total plastics production = 60.6 billion lb

Source: Society of the Plastics Industry

Many types of plastics are used by the construction industry

Acrylic-styrene-acrylonitrile: A two-phase thermoplastic material combining styrene-acrylonitrile copolymer and acrylic rubber. Can be coextruded over acrylonitrile-butadiene-styrene for weatherability of window frames. Produced by General Electric, BASF, Monsanto, and Dow Chemical.

Acrylics: Thermoplastic resins of acrylic esters or methacrylic esters. Typical applications are in lighting fixtures and glazing. Producers include Rohm and Haas, Cyro Industries, and ICI Americas.

Acrylonitrile-butadiene-styrene: A thermoplastic derived from acrylonitrile, butadiene, and styrene. Used to a limited extent in window frames. Producers include General Electric, Monsanto, and Dow Chemical.

Chlorinated polyvinyl chloride: A thermoplastic produced by the post chlorination of polyvinyl chloride resin. Uses include hot and cold water pipe, and industrial liquid handling. Produced by BF Goodrich.

Ethylene-vinyl acetate: A thermoplastic copolymer of ethylene and vinyl acetate. Uses include wire and cable insulation, and sewer pipe repair. Producers include DuPont, Exxon Chemical, Union Carbide, and Dow Chemical.

Melamine and urea formaldehyde: Thermosetting resins formed by the condensation reaction of formaldehyde with melamine or urea. Applications include a laminating resin for countertops and adhesives for wood, particle board, and plywood. Producers include Georgia-Pacific, Borden, and American Melamine.

Phenolic: A heat-cured thermoset formed by the reaction of phenol and formaldehyde. Used in electrical devices and as a plywood adhesive. Producers include Borden, Georgia-Pacific, Occidental Chemical, Monsanto, and AlliedSignal.

Polybutylene: A semicrystalline thermoplastic formed by polymerization of 1-butene. Used in residential hot and cold water pipe, and under-floor hydronic heating systems. Produced by Shell Oil.

Polybutylene terephthalate: A semicrystalline thermoplastic polyester formed in a transesterification reaction between 1,4-butanediol and dimethyl terephthalate. Used to form countertops and sinks. Producers are BASF, General Electric, and Hoechst Celanese.

Polycarbonate: An engineering thermoplastic usually based on bisphenol A reacted with carbonyl chloride. Applications include window and skylight glazing. Major producers are Dow Chemical, General Electric, and Miles.

Polyethylene: A family of thermoplastic resins obtained by polymerizing ethylene. Applications include pipe and wire and cable covering. Producers include Union Carbide, Solvay, Eastman Chemical, Exxon Chemical, Dow Chemical, and others.

Polyphenylene oxide: A thermoplastic produced through the oxidative coupling polymerization of 2,6-dimethylphenol. Used to make roofing panels. Produced by General Electric.

Polystyrene: High molecular weight thermoplastic resins produced by free-radical polymerization of styrene. Uses include insulation and sheathing. Producers include BASF, Amoco, Dow Chemical, and Huntsman Chemical.

Polyurethane: A family of polymers based on the reaction product of an organic isocyanate with compounds containing a hydroxyl group. Uses include insulation and roofing systems. Raw material manufacturers include ICI Americas, Miles, Dow Chemical, and BASF.

Polyvinyl chloride: A thermoplastic resin produced by the polymerization of vinyl chloride. Uses include siding, window frames, and moldings. Producers include Occidental Chemical, Vista Chemical, Borden, Geon, and Georgia Gulf.

Thermoset polyester: The condensation product of an unsaturated dibasic acid, such as isophthalic acid, and a glycol. Uses include cultured marble sinks and spas. Producers include Aristec, Ferro, Owens-Corning, and Reichhold.

Geon has developed a technology that allows the use of fiberglass-reinforced PVC in prefabricated housing, the use of which has potential for growth particularly in developing countries. The system for such a structure, which gets structural support from concrete pillars poured into the PVC framework, is under license to Royal Plastics in Toronto, Canada.

A variant on PVC, chlorinated polyvinyl chloride (CPVC), is widely used in high-temperature water distribution systems. BF Goodrich is the only U.S. supplier of the material. According to Frank J. Copa, the company's industrial systems senior marketing manager, growth prospects are good for CPVC in industrial applications as well as in residential housing applications for the pipe. The excellent corrosion resistance of CPVC over a wide temperature range, along with a good mix of mechanical properties, would give CPVC a better service life in chemical process industry than carbon and stainless steel now offer, he says.

Goodrich's CPVC resins are now available from pipe manufacturers in ½-inch to 18-inch diameters. Because the material has good flame retardance and low smoke generation, CPVC may also be used in light-service water sprinkler systems, says Copa.

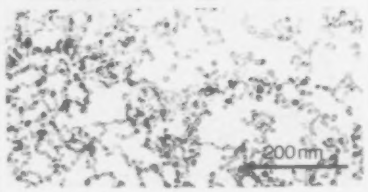
PVC is also used in the manufacture of geomembranes to line ponds and waste disposal sites, and for roofing. HPG International, the former plastics division of Hüls America, produces the wide sheets for these uses along with a line of polyolefin-based sheet. According to HPG president John P. Dellevigne, the roofing PVC business is doing well now, but the business tends to be cyclical, dependent on the ups and downs of the construction market.

Because neat PVC resin tends to be brittle without the proper additives, a number of PVC additives help extend the performance range of PVC. Lawrence Brecker, vice president of the polymer additives group for Witco, says his company is a leading provider of methyl, butyl, and octyl organotins used as heat stabilizers in PVC resins. The additives improve the resin's long-term weatherability.

Brecker says the company also supplies mixed metal heat stabilizers for flexible PVC, such as calcium/zinc- and barium/zinc-based compounds used in wire, cable, and flooring formulations.

Continued on page 28

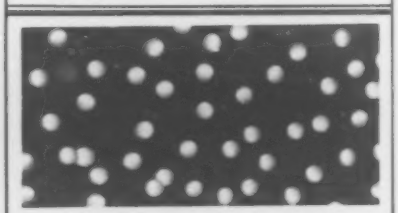
New Silica Sol is it !!



ST-UP chain molecules of silica. 5-20nm in width 40-300nm in length

ST-O negatively charged small particle sol (ca. 12nm), not including anion and cation without stabilizing ion

for Binder? Micro Filler? or?



Colloidal Silica dispersed in organic solvent.

Type	SiO_2%	Dispersant
IPA-ST	30	Isopropanol
EG-ST	20	Ethyleneglycol
DMAC-ST	20	Dimethylacetoamide
NPC-ST	20	Ethyleneglycol-mono-n-propylether

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CIRCLE 18 ON READER SERVICE CARD

Construction demand for plastics rising 4% annually

Millions of lb	1992	1997	% average annual change
Polyvinyl chloride	5,638	6,970	4.3%
Phenolics	2,252	2,630	3.2
Urea & melamine	1,404	1,770	4.7
Polyethylene	942	1,140	3.9
Polyurethane	875	1,085	4.4
Other resins	1,586	1,925	2.0
TOTAL	12,697	15,520	4.1%

Source: Freedonia Group

Value of PVC exceeds all other resins in construction

$ Millions	Estimated 1992	Projected 1995	% average annual change
Polyvinyl chloride	$1,792	$2,075	5.0%
Phenolics	1,122	1,235	3.3
Polyurethanes	925	1,059	4.6
Polyethylene	435	512	5.6
Polystyrene	330	383	5.1
Urea & melamine	272	297	3.0
Acrylics	256	298	5.2
Other	515	662	8.7
TOTAL	$5,647	$6,521	4.9%

Source: Frost & Sullivan

Witco was formerly a big supplier of cadmium-based stabilizer, but because of toxicity concerns over heavy-metal use, the company has discontinued heavy-metal additives. Other additives the company supplies for PVC are lubricants that ease the processing of PVC and blowing agents for PVC foam.

Jim Souder, plastic additives marketing manager for Rohm and Haas, says the acrylic additives his company supplies to PVC processors help improve both the impact resistance and the weatherability of PVC siding, window frames, and pipe. The acrylic additives, used at 5 to 10% of the weight of the final products, also aid in the melting and fusion of vinyl compounds prior to extrusion.

Elf Atochem competes with Rohm and Haas as a supplier of acrylic PVC additives, as well as with Witco as a supplier of organotin heat stabilizers. David Fultz, vice president and general manager of Elf Atochem's additives division, says the company has ongoing organotin research programs to improve the weatherability of dark-colored PVC so that vinyl can compete with dark-colored aluminum window frames. "The key to making PVC work," says Fultz, "is the additives."

Where dark-colored, all-PVC window frames are still not viable, Elf Atochem offers an option. An Elf Atochem spokesman says the company's polyvinylidene fluoride (PVDF) can be laminated or coextruded over PVC to extend the performance of dark-colored PVC window frames that might otherwise tend to crack because the dark colors allow greater heat buildup than PVC can usually withstand. Other construction uses are solid PVDF pipe—which, at five to 10 times the cost of comparable PVC pipe, can replace stainless steel drain pipes where corrosive liquids must be handled, such as in chemistry labs.

Other suppliers of PVC additives include Lonza and Uniroyal Chemical. Lonza's lubricants aid in faster processing of PVC siding, for instance. According to Tom Gazel, Lonza market-

Piping is largest segment of construction market for plastics

$ Millions	Estimated 1992	Projected 1995	% average annual change
Pipes, fittings & conduits	$1,662	$1,904	4.6%
Resin-bonded woods	1,130	1,238	3.1
Insulation	1,047	1,195	4.5
Siding & paneling	336	426	8.2
Flooring	467	522	3.8
Window profile extrusions	168	211	7.9
Vapor barriers	128	143	3.8
Glazing & skylights	397	503	8.2
Other	312	379	6.7
TOTAL	$5,647	$6,521	4.9%

Source: Frost & Sullivan

Worker tests efficacy of Air Products & Chemicals' polyurethane foam additives.

ing manager, the company offers both ethylene bisstearamide and glycerol ester lubricants. Uniroyal says its PVC blowing agent business is doing well as use of foam-core pipe grows. According to Casey Leone, specialty chemicals marketing manager, the company's azodicarbonamide blowing agents are also used in window frames, decorative moldings, and resilient vinyl flooring.

Although PVC may be making inroads into areas held by traditional building materials, some plastics are trying to displace PVC itself in some building and construction applications. General Electric, for instance, is promoting use of its acrylonitrile-butadiene-styrene (ABS) coextruded with colored acrylic-styrene-acrylonitrile (for weatherability) for use in window frames and siding. Deep colors of GE's coextruded plastics perform better in hot climates than competing PVC, says industry manager Paul M. Conroy. The materials have higher dimensional stability and resist heat buildup better, he says.

GE's materials are cost competitive with both aluminum and PVC, Conroy says, and he's confident they will find their niche as an alternative to those materials as well as to wood. Conroy estimates half of all window frames made today are made of wood, with aluminum at about 30% of the market and vinyl accounting for the remaining 20%. Currently, GE's penetration into the market is small, he admits.

Bob Ackley, president of the Davis-Standard division of Crompton & Knowles, says the company has frequently supplied multilayer extrusion equipment necessary for the types of siding and window frame coextrusions that GE is promoting. The technique is more widely used in food packaging, as well as in the production of automotive parts, he says. More recently, the technique has been applied to construction industry materials. For instance, vinyl window frames are being coextruded with a harder vinyl core and a soft vinyl outside where the frame and glass meet, providing a better seal between the vinyl and glass.

Polyurethane foam use

Polyurethane rigid foam insulation for roofs and walls was a $925 million business in 1992, estimates Frost & Sullivan. James R. Steiner, Miles Inc.'s lamination market manager, says Miles supplies the precursor isocyanates and polyols that manufacturers of the foam-board insulation need. Use of the foam in the housing market has increased along with housing starts, but its use in commercial buildings, either to insulate roofs or as insulation behind metal facings, has not been as strong.

Miles also supplies precursors for foamed-in-place insulation, says Steiner, to insulate garage and residential doors, for instance. Reaction injection molded polyurethane is also seeing use in door and skylight frames, in place of wood, vinyl, or aluminum.

Dow Chemical is another supplier of polyols and isocyanates, which are used to make polyurethane insulating board. Dow also supplies users with precursors for foamed-in-place polyurethane insulation in doors, says Cindy Elliott, marketing manager for rigid-foam applications. A new development is the use of foamed-in-place urethane to insulate large industrial refrigeration units and warehouses. Growing, too, on a small base, is the market for consumer-applied polyurethane insulation, which is dispensed from a pressurized can and sold at hardware stores and home centers.

Historically, polyurethane insulation has required the use of a chlorofluorocarbon (CFC) blowing agent in addi-

Continued on page 34

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CIRCLE 2 ON READER SERVICE CARD

General Electric, DuPont push construction plastics to limits in model homes

General Electric is a major plastics producer that would also like to be a major supplier to the building and construction market. About five years ago, the company splurged on the construction of a 3,000-sq-ft model home in Pittsfield, Mass., where the company's plastics business is headquartered.

About 30% of the house consists of plastic. According to GE, that amounts to 45,000 lb of plastic—and that is because GE set out to push the limits for this house, which contains many developmental construction products not widely in use today. Most new residential construction contains no more than 5% plastic, says GE's building and construction industry manager, Walter J. Bilinski, despite the seeming proliferation of plastics in flooring, molding, countertops, and plumbing.

But GE's new house contains a plastic roof. Very few homes today have such a roof. Bilinski says Eiger Building Products, Miami, Fla., has begun commercializing roofing sheets that look like cedar shake shingles made out of GE's polyphenylene oxide resins. Siding and window frames on the house are made from dark-colored acrylic-styrene-acrylonitrile coextruded over acrylonitrile-butadiene-styrene for better performance than polyvinyl chloride, says GE industry manager Paul M. Conroy.

Plumbing systems include polybutylene terephthalate sinks made from GE's resin. Window glazing at the house entry features GE's polycarbonate for security purposes. The plastic windows cannot be broken as easily as those made from more traditional glass.

Plastics in the house offer advantages, says Conroy. For example, they replace wood in window frames and siding, their thermal efficiency saves energy, and the low maintenance qualities endear them to consumers. In addition, notes Conroy, plastics are versatile, and so they can be designed to mimic the appearance of traditional materials or allow designers the freedom to come up with new designs.

Although Conroy is confident that plastics will continue to make inroads into the building and construction

C&EN staff photos

tion to the polyol and isocyanate components. Both Miles' Steiner and Dow's Elliott have noted that CFCs, implicated in the destruction of Earth's protective ozone layer, have all but been eliminated as polyurethane blowing agents. Thomas J. W. Gellrich, Elf Atochem's business manager for foams and specialties, says CFC blowing agents for polystyrene foam have been replaced as well. A number of fluorochemicals with low or no ozone depletion potential have replaced the CFCs, he says.

Hydrochlorofluorocarbons (HCFC) 141b and 142b are currently the best alternatives to CFCs, but they will be phased out by 2015, says Gellrich. Under development are fluorochemicals with no ozone-depleting potential, such as hydrofluorocarbon 134a, he says. Pentane, a CFC substitute, is flammable and yields a foam with poor insulating properties, says Gellrich. Another CFC substitute, cyclopentane, is flammable, does not have good insulating properties, and is also a volatile organic compound (a precursor of atmospheric smog), he says. Still another alternative blowing agent, carbon dioxide, is "okay," says Gellrich, but it also yields a foam with poor insulating properties.

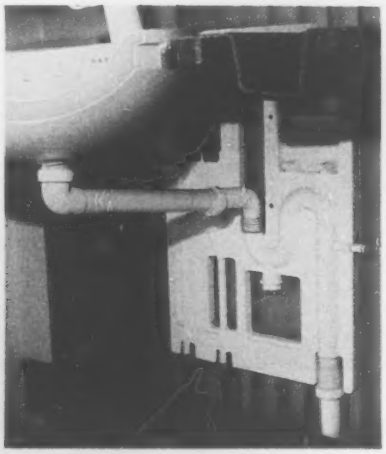
Peter Sullivan, industrial products business manager for Amoco Foam Products, says his company's expanded polystyrene (EPS) foam boards have been free of CFCs since January 1990. Like other manufacturers, Amoco declines to identify the specific blowing agent the company uses to convert its own EPS beads into foam boards. Amoco EPS boards are available in thicknesses of ½ to 3 inches, and provide insulation below ground around foundations, along sidewalls, and under roofing. A variation of Amoco's foam board is available with 50% recycled content, half of which is postconsumer material. It has almost the same insulation values, but shows a slight degradation in compressive strength compared with board made from virgin resin, says Sullivan.

Huntsman Chemical supplies block molders with EPS beads to form foam blocks and sheets. Marketing development manager Jim Shannon, says that years ago, molders made undifferentiated 4- × 8-foot EPS board stock to insulate buildings. Now, EPS boards are engineered into value-added "systems" in which the EPS sheet may be laminated to roofing and wallboard for insulation.

In a developing application, two 4- × 8-foot sheets of wood oriented strand board sandwich an EPS foam panel to provide a structural insulated panel system that may find use in the construction of new homes. The EPS panel has prerouted ducts to allow for electrical wiring and plumbing. The panel offers a 33 to 50% energy savings over conventional construction, and is cost competitive with conventional construction as well, says Shannon. However, this technology has not yet gained wide acceptance. Shannon sees further resistance ahead for the technology from carpenters' unions because a "house can go up in four days"—much less time than it takes using ordinary materials.

BASF also produces EPS beads, which Tom Greeley, business development manager, agrees are used mostly to form roof, wall, and foundation insulation panels. A developing use for EPS is in the construction of forms for concrete foundations. Two basic systems are used. One utilizes two EPS sheets separated by a space and held together with plastic ties to outline a foundation form. A builder pours concrete between the sheets, and the EPS is left in place. In a second system, a builder can mold a foundation with EPS building blocks. The builder fills the blocks with concrete to form a load-bearing foundation.

Almost one third of GE's new house is made of plastics.



markets, he acknowledges it will take some time before plastics use approaches anything near the 30% level in the GE model house. Wood and wood-based chip and flake boards will still find wide use as building studs, siding underlayment, and roofing decks. These materials are used in the GE house as well.

GE is not the only plastics manufacturer to build a "concept" house to showcase plastics used in construction. DuPont teamed up with builder Segal & Morel in the northern New Jersey town of Chester to build a 3,600-sq-ft two-story home. DuPont products used to construct the house include nylon resins for electrical outlets and switches, Corian acrylic for countertops and tub surrounds, a synthetic slate roof containing polyethylene pulp, Tyvek polyethylene fiber air-infiltration house barrier wrap, and laminated glass fabricated with polyvinyl butyral resin.

DuPont is also a big supplier to the home furnishings industry, so the home showcases domestic goods such as carpeting, upholstery, sheets, comforters, and curtains containing DuPont polyester and nylon fibers.

One advantage of these systems is that they retain moisture around the concrete, allowing for a longer and stronger cure. Also, since the EPS remains in place, it saves the labor of removing the wood forms used in conventional poured-foundation construction. In addition, because the EPS stays in place, it provides long-term insulation. And in earthquake-prone areas, the EPS acts as an energy absorber and earth stabilizer, says Greeley.

Although Frost & Sullivan estimates the size of the EPS market at $330 million, the polyethylene market is somewhat larger at $435 million. Christer Rundlof, Unipol polymers business manager for Union Carbide, says polyethylene is used for potable water distribution, natural gas distribution, and cable conduit. Because the plastic alone is not flame retardant, it is not often used inside buildings. Rundlof claims that polyethylene is a cost-efficient material to produce, extrude, join, and maintain. He estimates that polyethylene has captured 75 to 80% of the natural gas distribution market.

Because PVC becomes brittle at low temperatures, Rundlof thinks polyethylene could eventually replace PVC in sewer pipes. Polyethylene "has a much lower brittleness temperature than PVC," he says. And just as at least one

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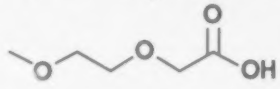
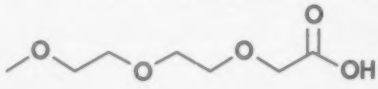
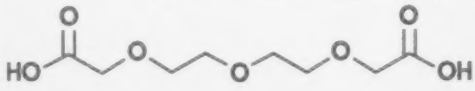
3.6-Dioxaheptanoic acid



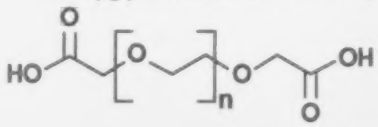
3.6.9-Trioxadecanoic acid



3.6.9-Trioxaundecanedioic acid



Polyglycol diacid (n = 10 - 12)



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CIRCLE 14 ON READER SERVICE CARD

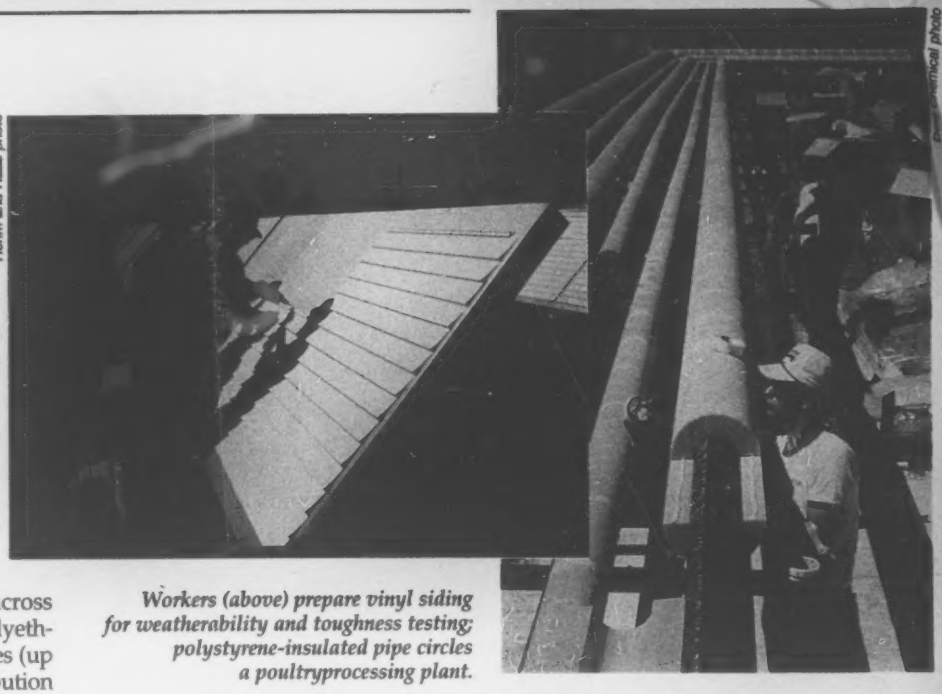
PVC producer, Vista, says PVC can be used to seal and reline old concrete and steel water and sewer pipe, polyethylene can also be used for the same purpose, says Rundlof.

Steve Sandstrum, pipe resin industry manager for Solvay Polymers, says increasing demand for large-diameter pipe for commercial and industrial use and continuing growth for natural gas distribution have kept the construction market for polyethylene fairly robust. One growing commercial use for polyethylene has been as a conduit for fiber-optic telecommunications lines being installed across the U.S. A burgeoning area for polyethylene use is in large-diameter pipes (up to 60 inches in diameter) in distribution systems for potable water.

Another potential growth market is polyolefin-based wire and cable jacketing. According to Grace Waag, Union Carbide's business manager for flame-retardant wire and cable materials, additives and fillers make the polyolefins flame retardant without the use of halogens. In contrast to halogen-containing coated wire such as PVC, the alternative-coated wire would give off fewer emissions and no toxic or corrosive gases in the event of fire. The cost of the jacketing materials is available at a 10 to 25% premium to conventional jacketing material, "but it is a small price to pay for fire safety, we think," says Waag.

Another polymer resin used in construction, melamine, is widely employed in the production of high-pressure laminates such as Formica-brand laminate and in low-pressure laminates such as wood particle board. Gordon Ruhf, process chemicals marketing director for Cytec Industries, expects the use of melamine adhesives to grow as lumber becomes more scarce in the U.S. and more scrap wood is converted into various types of particle boards.

Ruhf also sees a growing market for melamine crystal used as a scavenger in urea formaldehyde glues to prevent outgasing of toxic formaldehyde. Cytec produces melamine in a joint venture with Dutch chemicals producer DSM called American Melamine Industries. The partners split the output and individually market the melamine.



Rohm and Haas photo

Chemical photo

Workers (above) prepare vinyl siding for weatherability and toughness testing; polystyrene-insulated pipe circles a poultryprocessing plant.

Both acrylic and polycarbonate compete as glazing materials to replace glass in the building and construction market. Hal Ivy, marketing programs manager for ICI Lucite sheet, a business ICI Americas recently acquired from DuPont, says acrylic glazing is largely used as a security barrier. It is also used in lighting grids and skylights.

Acrylic sheet is used in thermoformed bathtubs and spas as well. Once the tub or spa is formed, it is backed with polyester-reinforced fiberglass to give the unit rigidity.

Ferro Corp. supplies polyester gel-coat resins to coat fiberglass-reinforced tub and bath units. According to Ben Froelich, Ferro director of sales and marketing, Ferro purchases an isophthalic-acid-containing polyester resin from a supplier such as Ashland Chemical and then adds color and diluents. The gel coat may then be sprayed to form a smooth-finish colored sink or tub. Jim Luke, gel-coat operations manager for Ferro, says gel-coat finished fixtures compete not only with the acrylic-sheet-formed bath fixtures, but also with those made of more traditional enameled steel.

Douglas G. Powell, building and construction marketing manager for polycarbonate producer Miles, says polycarbonate is a relatively small player in the construction market. He estimates that about 120 million lb of polycarbonate are used annually for glazing in skylights, vandal-resistant windows, and outdoor signs. The cost of polycarbonate somewhat limits its growth potential, but where its clarity and break resistance are valued, polycarbonate use will grow. One potential new market is for clear blocks, that when made out of lightweight polycarbonate, reduce installation cost and the fatigue of installing the much heavier glass blocks.

Another new polycarbonate market is corrugated sheet to replace fiberglass-reinforced polyester sheets now used to cover structures such as greenhouses. Powell says corrugated polycarbonate has superior strength, weatherability, and light transmission when compared with the fiberglass sheet. Still another new polycarbonate product is a double-wall sheet, with half the thermal conductivity of glass, for use in greenhouses and residential applications.

Strict new building codes in hurricane-plagued southern Florida will require tougher glazing to resist the impact of debris flung by a storm's winds. Polycarbonate may be able to compete in this market because of its excellent impact resistance, says Powell.

Building codes are also a consideration in GE's introduction of polyphenylene oxide (PPO) into roofing tiles. Roofing materials that contain plastic are "barely detectable," in the market now, says building and construction industry manager Walter J. Bilinski, but GE hopes that will change as new codes in communities along the California coast give PPO roofs an edge. Fires

Continued on page 41

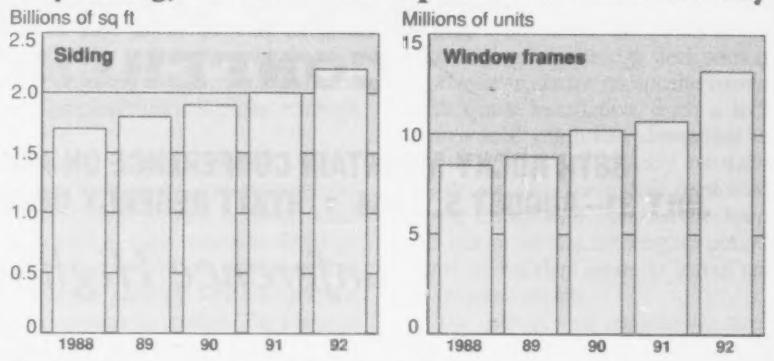
Continued from page 36

devastated many communities there last year. Flammable cedar shake roofs contributed to the fires' spread.

PPO panels can be made to look like wood and can easily achieve minimum fire-resistance ratings, whereas cedar requires special treatment to achieve that rating. In addition, Bilinski says he thinks PPO installation systems will ultimately achieve the highest fire-resistance rating, class A. The PPO panels are easy to install and save labor. One manufacturer's PPO panel requires only five nails to install, whereas an installer would have to drive 26 nails to get comparable coverage with individual cedar shake shingles.

With a cost of about $170 for materials to cover 100 sq ft, PPO roof tile is less expensive than slate (a look it can also achieve), competitive with cedar shake, and somewhat higher than clay tile. Bilinski figures that about $1 billion goes to purchasing those competitive residential roofing materials annually. He hopes to see PPO roofing materials gain a considerable share of that market.

Vinyl siding, window frame shipments have risen steadily



Source: Vinyl Siding Institute, division of the Society of the Plastics Industry

Another residential market GE hopes to tap is the countertop and sink market. Formica Corp. is now distributing GE's polybutylene terephthalate (PBT) sheet, a thermoplastic polyester that competes with melamine-based laminates, thermoset acrylics, and other thermoset polyesters. Because it is a thermoplastic material, PBT can be thermoformed into a sink, allowing for seamless joining of the sink with a PBT countertop, says Mark H. Hindal, GE Plastics business leader. The material's use is only in its infancy in the $1.3 billion countertop

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CIRCLE 33 ON READER SERVICE CARD

market, but Hindal also sees a potential market for PBT sheet in bath, shower, and tub surrounds.

Composite inroads are tentative

A small market exists today for all-plastic buildings. According to David Goodwin, product manager for the Composite Technology unit of W. R. Grace, the company can provide complete buildings of plastic for use in very corrosive environments, as well as for electronics industry companies that must conduct FCC tests of electronic equipment in environments free from electromagnetic radiation.

The Grace unit has annual sales of between $13 million and $16 million of composite plastics and fiberglass components for building and construction. In addition to all-plastic buildings, the Grace unit supplies fiberglass-reinforced polyester or vinyl ester panels to replace aluminum or steel panels that have corroded, or for new construction. It can also supply plastic-fiberglass structural beams as one-for-one replacements for steel beams in both new and existing buildings. The beams are so strong because they are "pultruded," a process by which continuous glass fiber is pulled through a resin bath. The polyester, vinyl ester, or other resin is then polymerized as the plastic-fiberglass matrix is pulled through a steel dye.

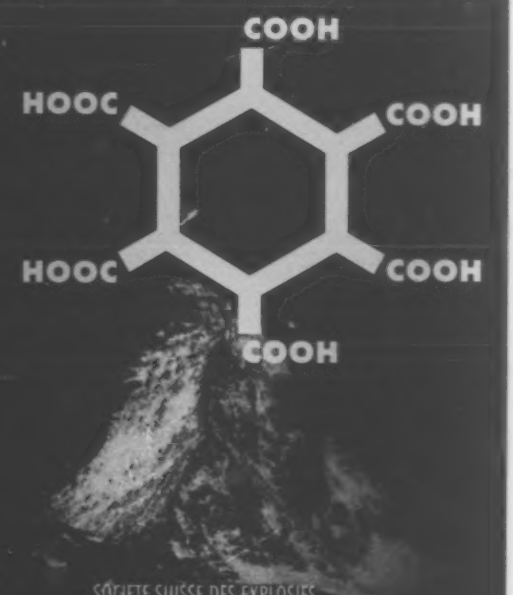
Composites such as those Grace's composite technology unit supplies occupy the middle ground between what Steve Borleske, new business development manager of DuPont advanced material systems, calls the low-end and the high-end composite market. The low end includes fiberglass composite baths and spas, and the high end includes advanced aerospace and sporting goods components.

In addition, DuPont is studying fiberglass or carbon-fiber-reinforced polyester or vinyl ester for use in "middle-ground" civil engineering structures. Systems to repair or build bridges and roadways are markets DuPont is targeting, says Borleske. The company hopes to make its mark as a manufacturer of large composite parts using other manufacturers' fiberglass, vinyl esters, or other materials.

Borleske envisions the possibility of prefabricating large bridge deck sections of corrosion-resistant composite materials for quick installation. Such a technique would minimize downtime on busy urban bridges, quickly returning roads to service. Traditional reinforced-concrete bridge deck construction keeps roads out of service for lengthy periods of time as builders labor to install and cure concrete on site.

In the case of civil engineering structures, DuPont is targeting customers such as state departments of transportation. But while university- and government-sponsored research has gathered considerable data on composites for infrastructure improvements, the technology does not have a long track record, Borleske admits. Still, DuPont thinks it will ultimately be able to show federal and state governments that plastic composites will offer both installation and life-cycle costs comparable to or better than existing techniques. □

CYCLOHEXANE HEXACARBOXYLIC ACID



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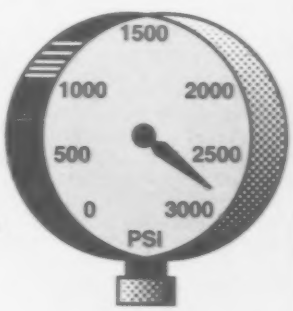

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